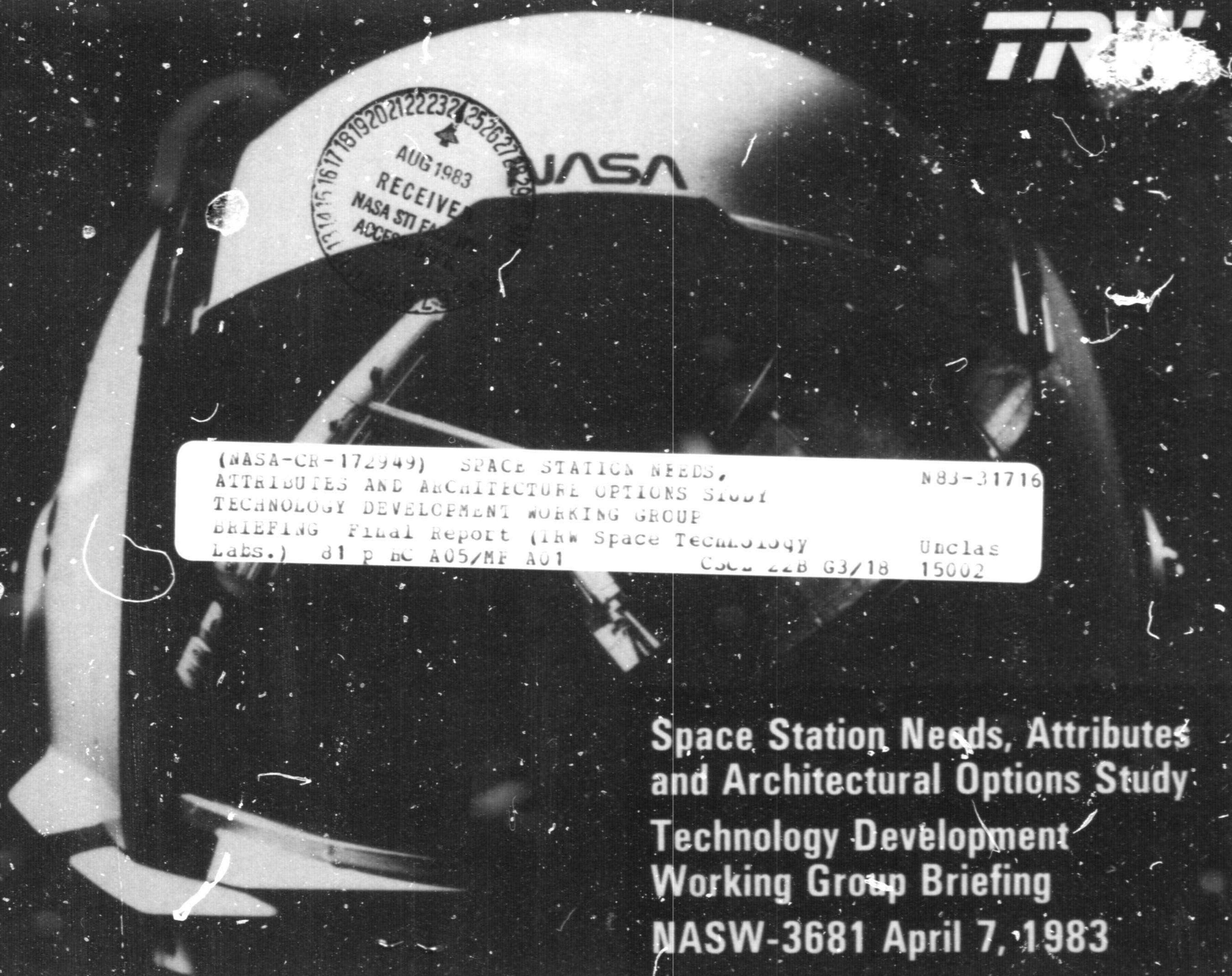
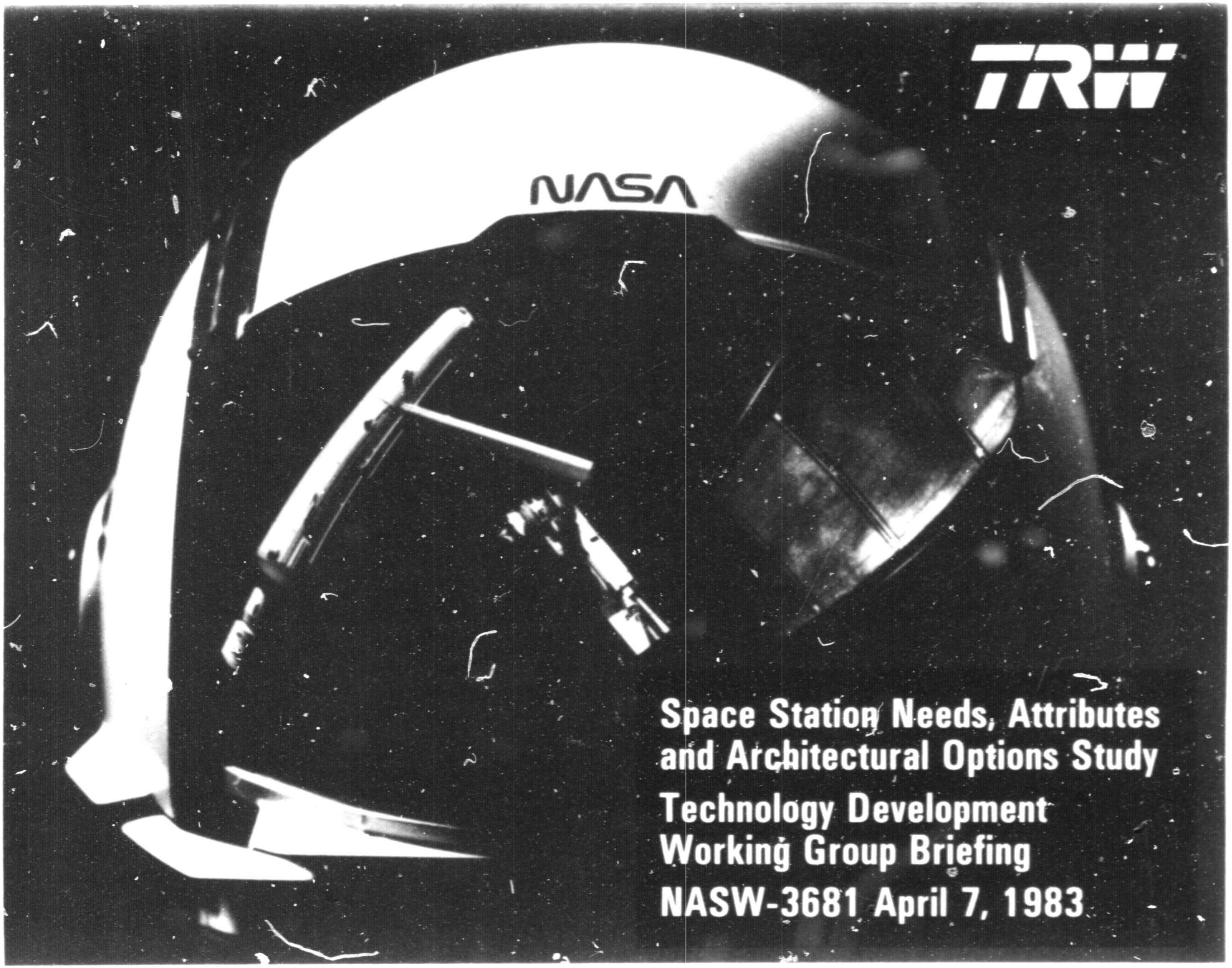


(NASA-CR-172949) SPACE STATION NEEDS, ATTRIBUTES AND ARCHITECTURE OPTIONS STUDY TECHNOLOGY DEVELOPMENT WORKING GROUP BRIEFING Final Report (TRW Space Technology Labs.) 81 p HC A05/MF A01 CSCL 22B G3/18 N83-31716 Unclas 15002

Space Station Needs, Attributes and Architectural Options Study

Technology Development Working Group Briefing

NASW-3681 April 7, 1983


TRW
NASA
Space Station Needs, Attributes
and Architectural Options Study
Technology Development
Working Group Briefing
NASW-3681 April 7, 1983

AGENDA

- SS Technology Needs
  - Assumed low risk technology
  - Enhancing technology
  - Applicable technology activities
- Technology Development Missions

ASSUMED LOW-RISK TECHNOLOGY-INITIAL SS

The next three charts list, by technology area, those technologies assumed in our architecture/configuration for the initial (1990) SS. The criterion is general lack of risk, as demonstrated by existing or near-term demonstration of each technology.

With these assumed technologies, no technical break-throughs are required to build and operate an initial Space Station or a Space Platform. Enhancing technologies (later charts) could emerge soon enough to be used in the initial configurations, particularly where their payoff is high.

In general, the Orbiter technology offers a firm baseline. Some improvements are necessary or highly desirable. Three such improvements would be:

- Fiber optic data bus. This is necessary so that all of the evolving subsystems have the ability to grow and change without changes to the data bus. The data bus forms a "spinal cord" of the SS. It should have bit rate capabilities much higher than initially needed and have unchanging interfaces.
- Partial water reclamation: This has the greatest weight-saving potential of any ECLSS technologies and is the most risk free.
- Improved space suit: Elimination of the pre-breathing requirements, while retaining mobility in the space suit is vital. Also desirable would be an improved thermal control system that does not consume water and rechargeable batteries.

ASSUMED LOW-RISK TECHNOLOGY - INITIAL SS

- DATA MANAGEMENT
  - FIBER OPTIC DATA BUS
  - DISTRIBUTED PROCESSING
  - AUTOMATED SUBSYSTEMS
  - DATA REDUCTION
- ENVIRONMENTAL CONTROL AND LIFE SUPPORT
  - PARTIAL WATER RECLAMATION
  - CO_2 COLLECTION AND DUMP
  - NO O_2 RECOVERY
  - STORED N_2 SUPPLY
- HUMAN CAPABILITIES
  - LIMITED AUTOMATION/ROBOTICS
  - TELEPRESENCE
  - IMPROVED SPACE SUIT - NO PRE-BREATH

ASSUMED LOW-RISK TECHNOLOGY-INITIAL SS (Continued)

The initial SS should have greater autonomy from the ground than the Orbiter now has. Both the SS and the ground operations also need increased automation to relieve and reduce the crew of repetitive, non-critical activities.

The initial SS, which will be relatively small, can use existing attitude control and dynamics methods. The anticipated pointing requirements on the SS are modest, so the primary problem will be dynamic stability.

The assumed batteries and solar array are current state-of-the-art. High voltage distribution (and switching) will be necessary to reduce bus weight and distribution losses. The distribution voltage and frequency (if ac) will need to remain fixed in the evolving SS. Automated power management is essential.

In the thermal control area the general plumbing must be configured initially, allowing changes in components, radiators, etc. with evolution. A no-phase-change pumped fluid system appears to be a reasonable baseline.

ASSUMED LOW-RISK TECHNOLOGY - INITIAL SS (CONT.)

- SYSTEMS/OPERATIONS
  - PARTIALLY AUTOMATED GROUND OPERATIONS
  - EVACUATION OF SS CREW VIA ORBITER
  - PARTIALLY AUTOMATED OPERATION
- ATTITUDE CONTROL AND STABILIZATION
  - RIGID BODY DYNAMICS
  - CO-LOCATED SENSORS AND ACTUATORS
  - CONTROL MOMENT GYROS
- POWER
  - LIGHTWEIGHT SILICON SOLAR ARRAYS
  - NICD BATTERIES
  - HIGH VOLTAGE DISTRIBUTION
  - COMPUTERIZED POWER MANAGEMENT
- THERMAL
  - PUMPED FLUID LOOPS
  - CONVENTIONAL RADIATORS
  - CONDUCTIVE COLD PLATES

ASSUMED LOW-RISK TECHNOLOGY-INITIAL SS (Continued)

Bi-propellant hydrazine appears to be the best propellant for the early SS. Transfer of tanks, either separately (a reboost module) or as part of the Logistics Module, would seem the best resupply method.

The main development needed for mechanisms is the docking/berthing mechanism. This is a device that would not be easy to change in future evolutions. It must anticipate all future needs (interfaces, etc.) in its design.

The initial communications needs would assume the use of TDRSS for a relay satellite. The Global Positioning Satellite capabilities must be included. Not mentioned is all other communications to STS, other satellites, EVA, IVA, etc.

ASSUMED LOW-RISK TECHNOLOGY - INITIAL SS (CONT.)

- AUXILIARY PROPULSION
  - BIPROPELLANT HYDRAZINE
  - TANK TRANSFER
- STRUCTURES AND MECHANISMS
  - COMPOSITE MATERIALS
  - REMOTELY CONTROLLED DOCKING/BERTHING MECHANISM
  - RMS-TYPE MANIPULATORS
- COMMUNICATIONS
  - STAY WITHIN TDRSS CAPABILITIES
  - DIGITAL COMMUNICATIONS
  - GPS

ENHANCING TECHNOLOGY FOR GROWTH SS

The next three charts list, by technology area, those technologies which would best enhance the interim and growth SS. These technologies would offer significant advantages of cost and/or performance. They could be introduced as they become feasible, using the concept of a SS with modular subsystems using orbital replacement units (ORU"s).

These technologies would reduce resupply mass and interval, would increase subsystem and component life, would allow more autonomy from the ground, more automation and fault tolerance on board, and would increase the data rate capability. More comforts could be provided for the crew. Better operational capabilities would be available so that the SS could do more, more effectively.

Highlights of the first chart are:

- Need for increasing automation on-board the SS. This requires better memories, fault-tolerant computers and software and improved computer/crew interface equipment.
- Improvements in the ECLSS would reduce resupply needs. Most important is reducing water and oxygen resupply. An integrated H_2/O_2 system may be the solution. This could also have advantages to the electrical power and propulsion systems.
- Further improvements in the space suit could make the power, cooling and oxygen systems closed cycle. Improved robotics and telepresence would reduce crew hazards and provide enhanced remote operations.
- To allow for reuseable OTV's, refueled at the SS, methods of supplying, transferring and storing cryogens would be needed.

ENHANCING TECHNOLOGY FOR GROWTH SS

- DATA MANAGEMENT
  - IMPROVED MASS MEMORY DEVICES
  - FAULT TOLERANT COMPUTERS/SOFTWARE
  - ADVANCED CREW/DISPLAY INTERACTIONS
  - INCREASED ON-BOARD AUTONOMY/AUTOMATION
- ENVIRONMENTAL CONTROL AND LIFE SUPPORT
  - COMPLETE CLOSED-LOOP WATER SYSTEM
  - INTEGRATED HYDROGEN/OXYGEN SYSTEM
  - O_2 RECOVERY
- HUMAN CAPABILITIES
  - INCREASED AUTOMATION/ROBOTICS
  - MORE SOPHISTICATED TELEPRESENCE
  - CLOSED CYCLE SPACE SUIT
- SYSTEMS/OPERATIONS
  - CRYOGEN RESUPPLY/STORAGE
  - DECREASED RELIANCE ON GROUND

ENHANCING TECHNOLOGY FOR GROWTH SS (Continued)

As the SS gets larger and more flexible, methods for dynamic control of the various portions becomes essential. Listed are some of these methods.

Enhancements to the electrical power system could include improved solar arrays and batteries, as well as alternatives to batteries, such as inertia wheels and regenerative fuel cells (possibly part of an integrated H_2/O_2 system). Nuclear power offers a possible long-term solution to electricity supply, assuming the safety issues could be solved.

Improved radiators appear to be the most significant thermal enhancement. They could provide smaller area and increased life. A multi-phase thermal approach may have merit, but the initial plumbing must be configured for such an accommodation.

ENHANCING TECHNOLOGY FOR GROWTH SS (CONT.)

- ATTITUDE CONTROL AND STABILIZATION
  - ADAPTIVE CONTROL
  - FLEXIBLE BODY CONTROL
  - IMPROVED SENSORS
  - DISTRIBUTED SENSORS/ACTUATORS
- POWER
  - GAAS CONCENTRATOR SOLAR ARRAYS
  - NiH_2 BATTERIES
  - INERTIAL ENERGY STORAGE
  - REGENERATIVE FUEL CELLS
  - NUCLEAR
- THERMAL
  - MULTIPHASE SYSTEMS
  - HEAT PIPE RADIATORS
  - LIQUID DROPLET RADIATORS

ENHANCING TECHNOLOGY FOR GROWTH SS (Continued)

The SS propulsion may be upgraded to some combination of cryogens, resistojets, or electrical/ion, depending on available cryogens and electrical power. The desire would be to reduce resupply requirements.

Improvements in the structures and mechanisms would be of an add-on nature. Mobile manipulators are an apparent need.

The communications needs are increased data rate and reductions in antenna size, number and complexity. Laser communications is an excellent prospect for the future.

ENHANCING TECHNOLOGY FOR GROWTH SS (CONT.)

- AUXILIARY PROPULSION
  - BIPROPELLANT CRYOGENIC
  - ELECTRICAL/ION
  - INTEGRATED H_2/O_2
  - RESISTOJETS
- STRUCTURES AND MECHANISMS
  - ADVANCED COMPOSITE MATERIALS
  - AUTOMATED CONSTRUCTION TECHNIQUES
  - IMPROVED THERMAL COATINGS
  - VERY LARGE STRUCTURE CONSTRUCTION
  - MOBILE MANIPULATORS
- COMMUNICATIONS
  - OPTICAL LINKS
  - 20/30 GHz LINKS
  - ELECTRONICALLY STEERABLE ANTENNAS
  - DATA/BANDWIDTH COMPRESSION
  - REDUCED ANTENNA QUANTITY

TRW TECHNOLOGY ACTIVITIES APPLICABLE TO SS

TRW has done, is doing, and has firm plans to do, a great many activities in support of development of technologies applicable to a SS or SP. The next three charts provide a brief listing of the more significant of these activities.

TRW is eager to share its research with NASA and DoD in these technologies. We are active industry participants in the NASA SS Technology Working groups.

TRW has a number of on-going research activities in data management systems. We have built and operated fault-tolerant computers. We are developing fibre optic data bus systems.

Our large ORU has been thermally and structurally tested and will be tested underwater for handling in 1983 at MSFC. We have a number of studies on man/machine interfacing, maintainability, and on-orbit servicing.

TRW TECHNOLOGY ACTIVITIES APPLICABLE TO SS

- DATA MANAGEMENT
  - DISTRIBUTED MICROPROCESSOR
  - FAULT-TOLERANT MULTIPROCESSOR
  - AUTONOMOUS SYSTEMS
  - RADIATION HARDENED ELECTRONICS

- HUMAN CAPABILITIES
  - MAN/MACHINE INTERFACING
  - UNDERWATER ORU TESTS

- SYSTEMS/OPERATIONS
  - ON-ORBIT SERVICING
  - LARGE STANDARD ORU
  - MAINTAINABILITY ON-ORBIT

TRW TECHNOLOGY ACTIVITIES APPLICABLE TO SS (Continued)

TRW has IR&D activities on control of large, flexible spacecraft. These include structural dynamic modelling, structural sensing and control, and adaptive techniques.

A number of different power technologies are under development at TRW (see subsequent charts for examples). These components or methods are all aimed at efficient, light-weight, long-life systems in the 20-500 kW range.

TRW is developing thermal technology in the areas shown. The ORU thermal testing was previously mentioned. We have also built and tested zero-leakage fluid valve disconnects having low pressure drop.

TRW TECHNOLOGY ACTIVITIES APPLICABLE TO SS (CONT.)

- ATTITUDE CONTROL AND STABILIZATION
  - LARGE SPACE STRUCTURES
  - STRUCTURAL SENSORS AND ACTUATORS
  - ADAPTIVE CONTROL
- POWER
  - ULTRALIGHT SOLAR ARRAY
  - CONCENTRATOR SOLAR ARRAY
  - HIGH POWER SWITCHES AND CONVERTERS
  - POWER MANAGEMENT
  - VERY LARGE POWER SUBSYSTEMS
- THERMAL
  - HEAT PIPE COOLING
  - COLD PLATE TECHNOLOGY
  - FLUID VALVES

TRW TECHNOLOGY ACTIVITIES APPLICABLE TO SS (Continued)

The TRW resistojet development has demonstrated enhanced performance and long life from these thrusters. We are actively involved in up-coming Orbiter fluid transfer demonstrations.

We have developed and tested both a berthing mechanism and a large ORU (see later charts). We are a leader in composite material application.

TRW is also a leader in laser and millimeter wave technology, and in secure communications and digital communications technology. We have built and flown and are doing advanced work in electronically steerable antennas (see later charts).

TRW TECHNOLOGY ACTIVITIES APPLICABLE TO SS (CONT.)

- AUXILIARY PROPULSION
  - RESISTOJET
  - PROPELLANT TRANSFER
- STRUCTURES AND MECHANISMS
  - BERTHING MECHANISM
  - BERTHING SIMULATIONS
  - ORBITAL REPLACEMENT UNITS
  - VERY LARGE STRUCTURE CONSTRUCTION
- COMMUNICATIONS
  - MICROWAVE/MILLIMETER WAVE TECHNOLOGY
  - LASER COMMUNICATIONS
  - SECURE COMMUNICATIONS
  - PHASED ARRAY ANTENNAS

TRW LIGHT-WEIGHT SOLAR ARRAY

This chart highlights some of the activities at TRW on light-weight solar array development and testing. The entire solar array wing, as well as the individual boxes are replaceable on-orbit as orbital replacement units (ORU's).

Deployment has been successfully tested at zero-g and at low-g levels both using an air bearing deployment test fixture and KC-135 simulation. Replacement of the array wing as an ORU has been tested in underwater testing at MSFC.

TRW LIGHT-WEIGHT SOLAR ARRAY

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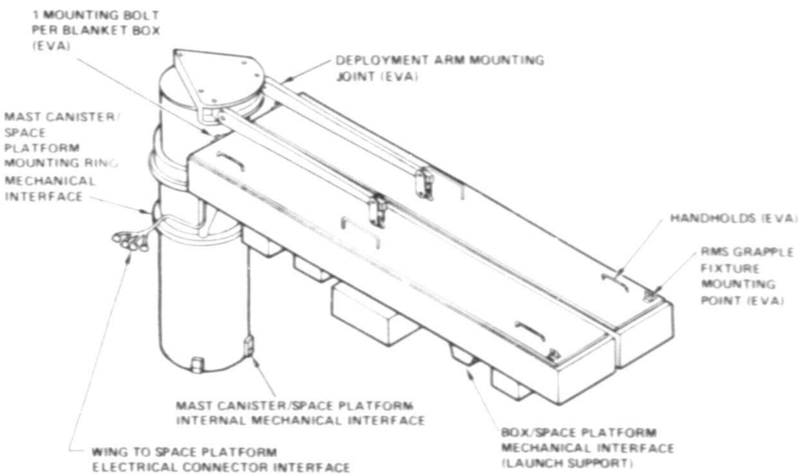
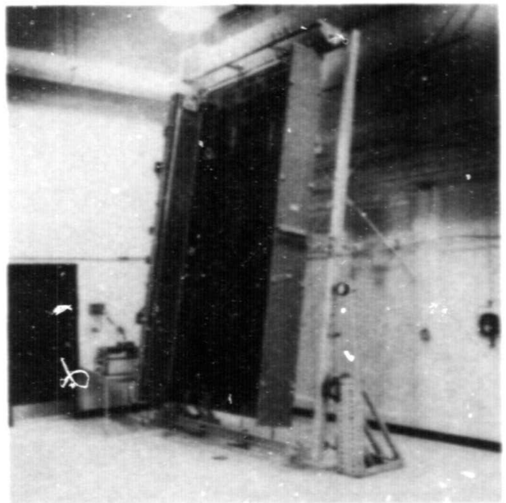
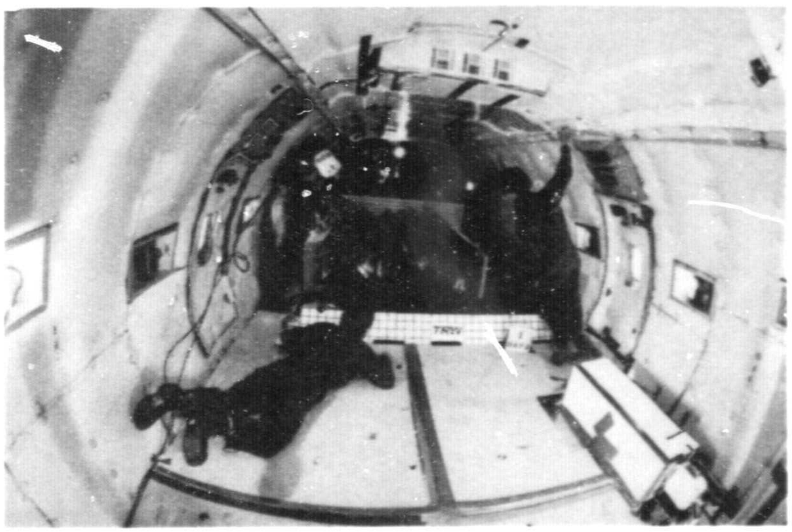


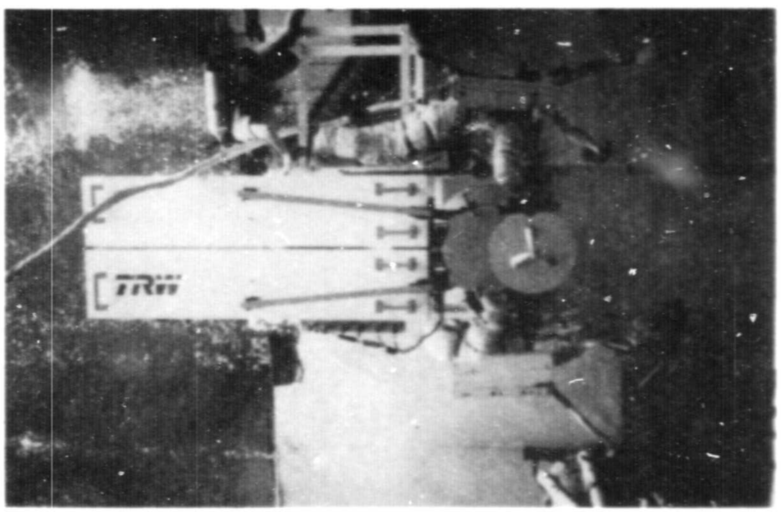
FEATURES ALLOWING ON-ORBIT REPLACEMENT



SOLAR ARRAY IN DEPLOYMENT TEST FIXTURE



KC-135 SIMULATED ZERO-G TESTING

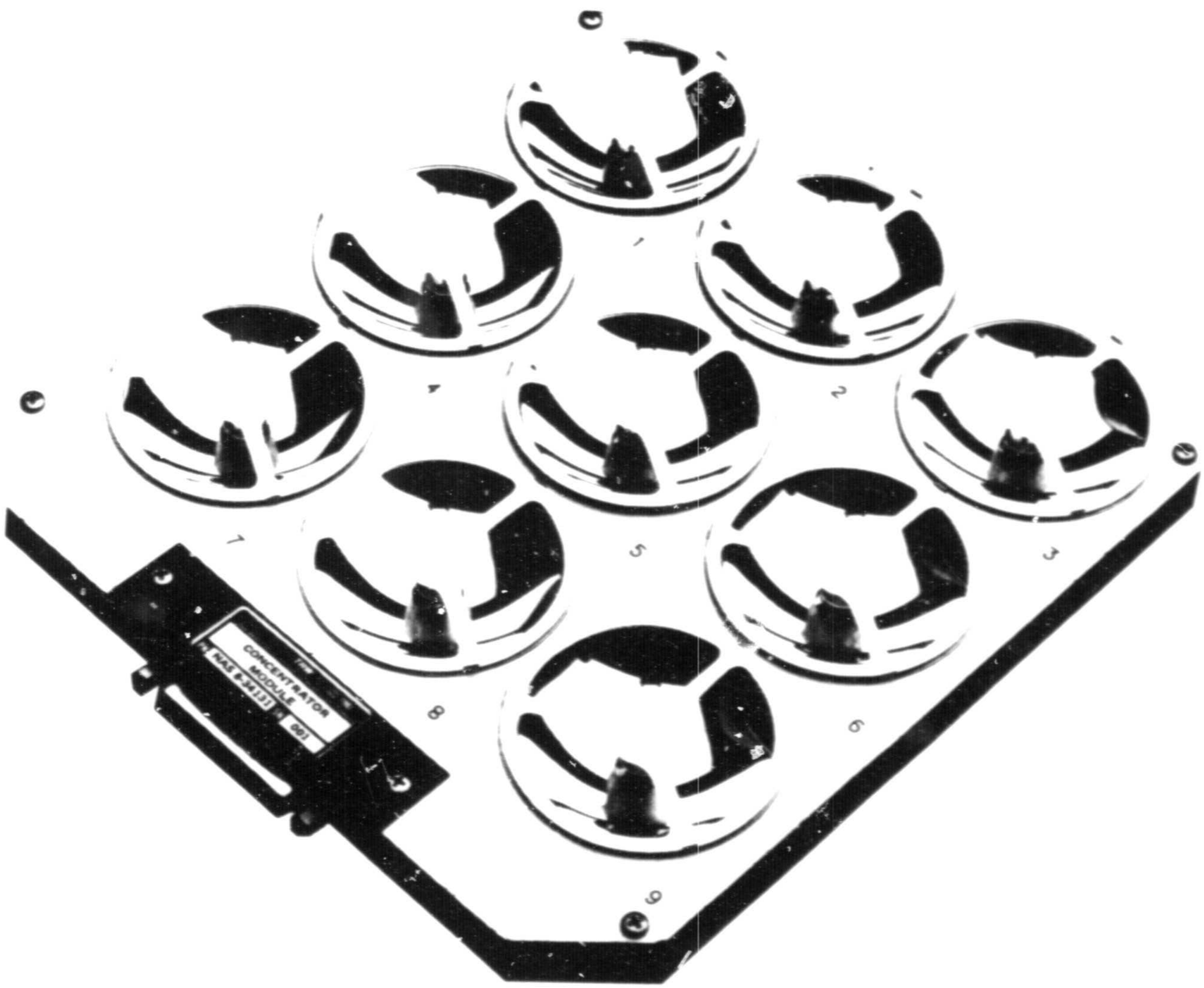


UNDERWATER ASTRONAUT HANDLING TESTS

TRW CASSERGRAINIAN CONCENTRATOR SOLAR ARRAY DEMONSTRATION MODULE

TRW has been active in the development of concentrator solar array technology. Shown is a nine element module using GaAs cells developed for NASA/MSFC. Early experience with this technology shows that a 33% reduction of solar array area for equivalent end-of-life power is achievable.

TRW CASSEGRAINIAN CONCENTRATOR SOLAR ARRAY DEMONSTRATION MODULE



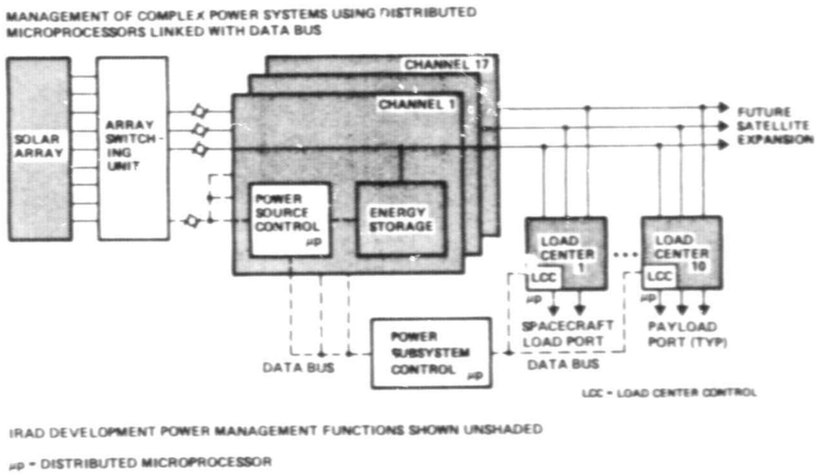
TRW ELECTRICAL POWER MANAGEMENT AND CONTROL ACTIVITIES

A number of study contracts, supplemented by IR&D, has enabled the development of advanced power management and control techniques and hardware. Subsystem autonomy can save operations costs and provide greater reliability, longer life and improved fault tolerance.

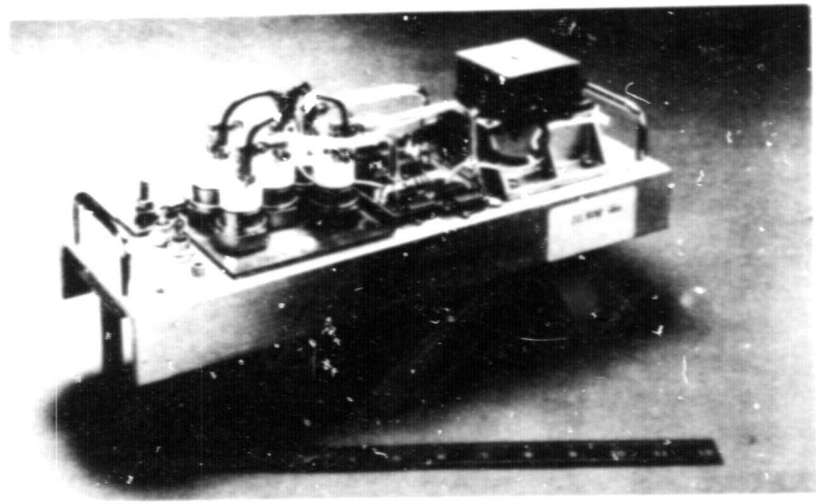
Two of the high power components needed have been breadboarded and tested. They are a high power switch and a transformer coupled converter. The latter is a high-efficiency voltage converter/regulator capable of multiple-voltage outputs at high power.

Program Management Division
TRW Space & Technology Group

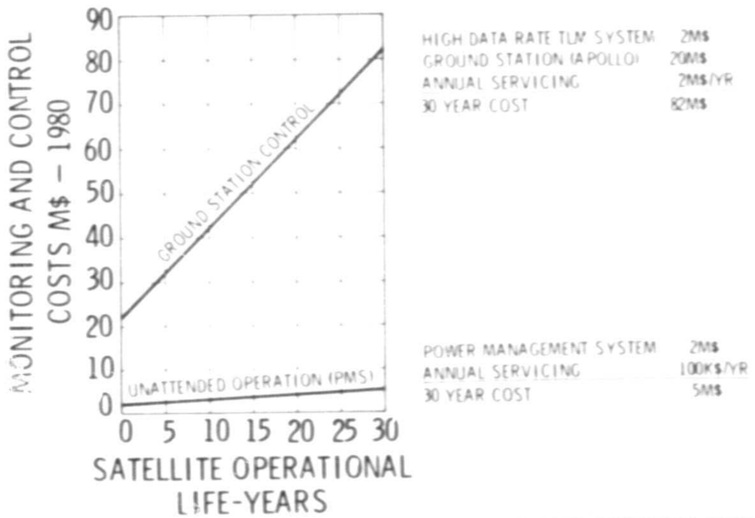
TRW ELECTRICAL POWER MANAGEMENT AND CONTROL ACTIVITIES



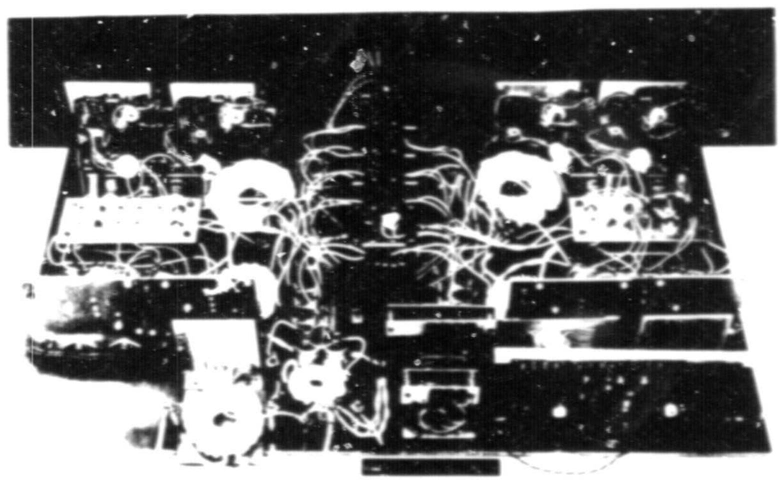
MULTICHANNEL ELECTRICAL POWER SYSTEM DESIGN



HIGH POWER (200V, 200A) SWITCH BREADBOARD



POWER MANAGEMENT REDUCTION IN OPERATIONS COSTS



TRANSFORMER COUPLED CONVERTER BREADBOARD

TRW BERTHING MECHANISM DEVELOPMENT AND TEST

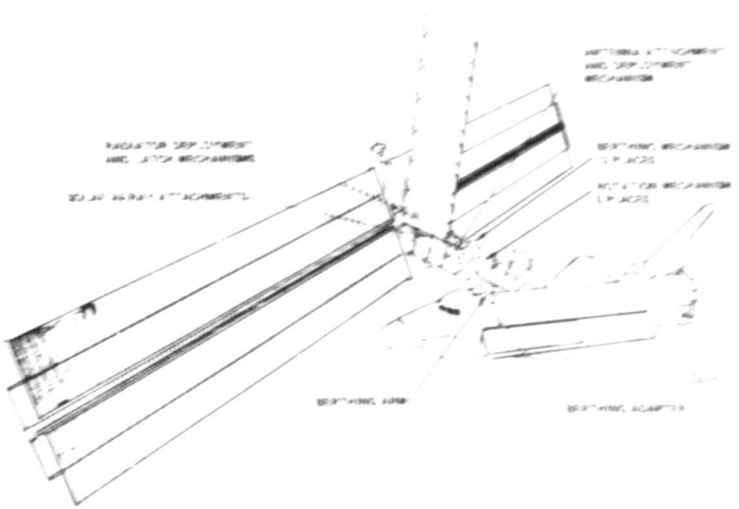
TRW has developed and tested a berthing mechanism suitable for all Space Station and Space Platform applications where a crew passageway is not required. Payload berthing and modular appendage attachment are typical applications.

The berthing mechanism is remotely controlled. It automatically accommodates moderate misalignments and provides for electrical and fluid connections.

An engineering model was tested at MSFC on the six degree-of-freedom simulator. Tests simulating the dynamics of a Space Platform berthing with an Orbiter were run.

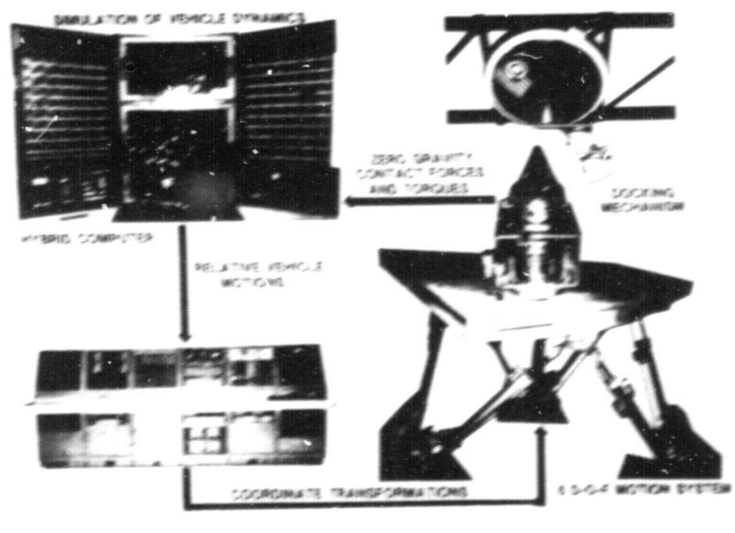
Program Management Division
TRW Space & Technology Group

TRW BERTHING MECHANISM DEVELOPMENT AND TEST

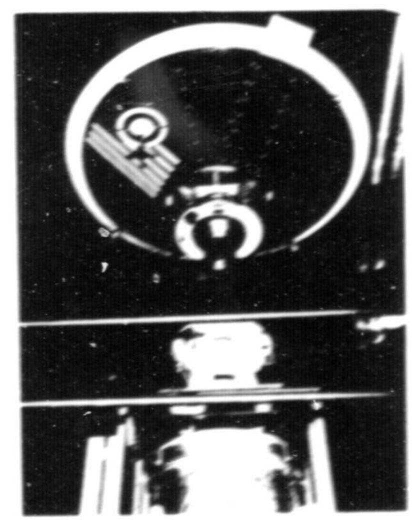


MECHANISMS ON A SPACE PLATFORM

CUTAWAY OF TRW BERTHING MECHANISM



MSFC SIX DEGREE-OF-FREEDOM SIMULATOR FACILITY



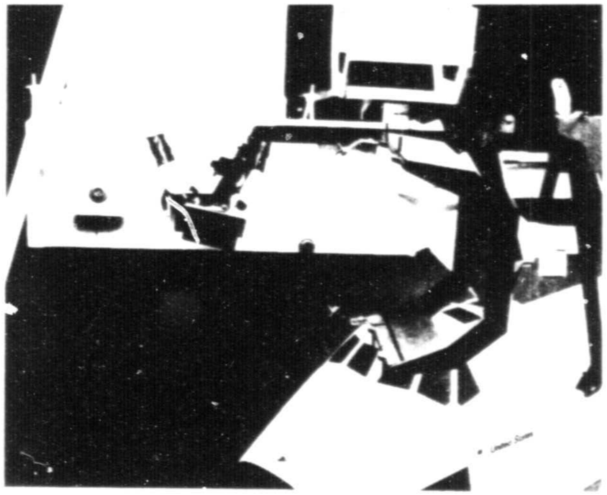
BERTHING MECHANISM ON SIMULATOR

TRW ORBITAL REPLACEMENT UNIT (ORU) DEVELOPMENT AND TEST ACTIVITIES

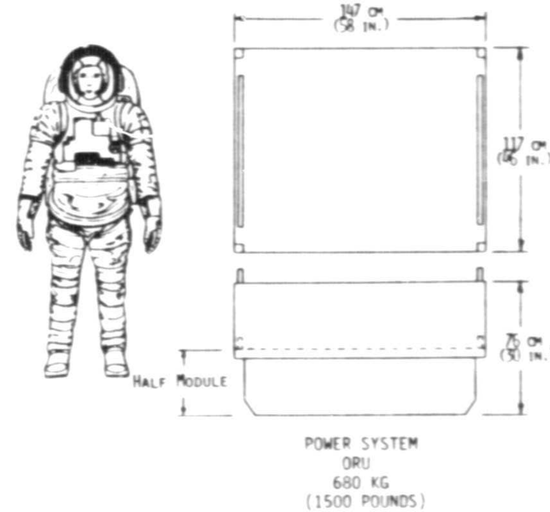
TRW has developed a concept for large-sized ORU's for Space Stations or Space Platforms. Each ORU would contain a portion of a subsystem, allowing on-orbit changeout for repair, maintenance, or technological upgrade.

Two different models of ORU cold plates have been thermally tested. A complete ORU mockup has been built and will be used in under-water handling and mating tests at MSFC in 1983.

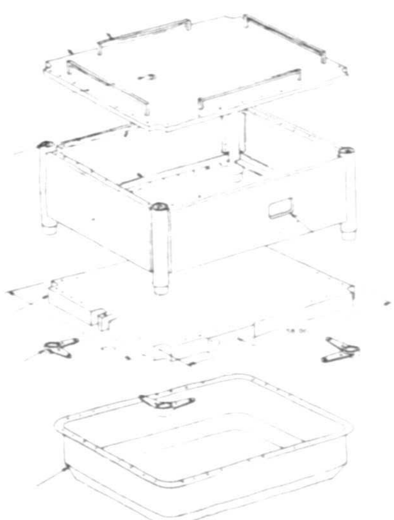
TRW ORBITAL REPLACEMENT UNIT (ORU) DEVELOPMENT AND TEST ACTIVITIES



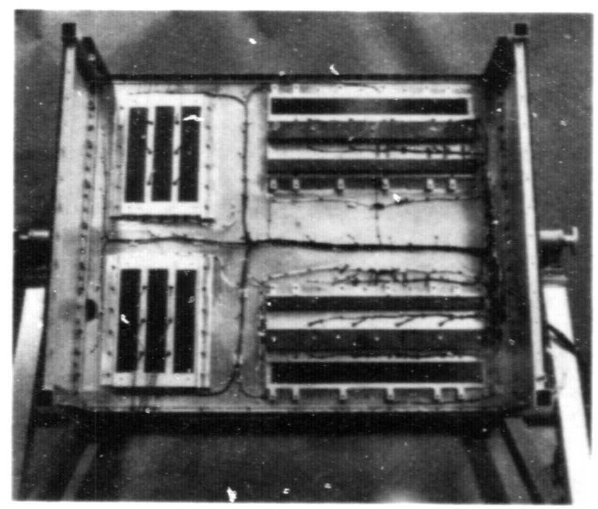
MODEL SHOWING ORU REPLACEMENT



ORU SIZE



ORU DESIGN



INSTRUMENTED ORU FOR THERMAL TESTING

COMMUNICATIONS TECHNOLOGY

Shown are a number of the new technology communications devices being developed at TRW. The first picture illustrates the TDRS multiple access phased array which can provide multiple beams for coverage of low altitude orbit satellites. It drives a multiaccess receiver system which can handle up to 20 S-band channels simultaneously. The Ku band 70 inch monopulse tracking antenna provides an 85 Mb/s plus 15 Mb/s link from LANDSAT to TDRS. The LANDSAT package provides a general purpose space-to-space user-to-TDRS link with a maximum capability of 170 Mb/s. Millimeter/microwave hwardware illustrated includes junctions, isolators, filters, transmission lines and diode mixers at frequencies from 7 GHz to 60 GHz.

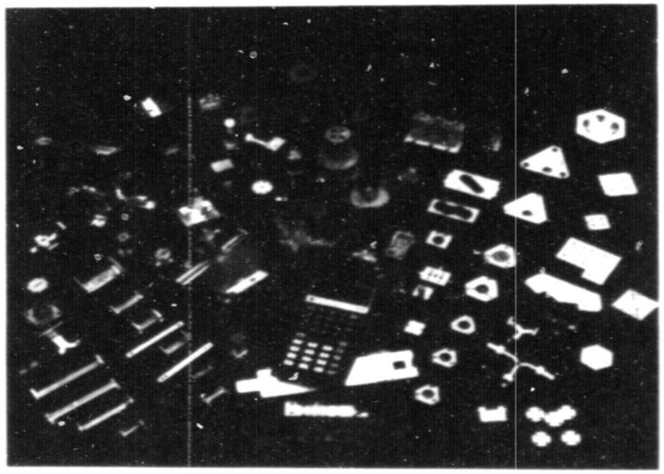
The two 20 GHz amplifiers illustrate two approaches to the design of a 10 watt solid state space transmitter. The GaAs FET amplifier provides more bandwidth and less noise than the IMPATT and is more suitable to the ring-type couplers. The IMPATT design, however, is currently more adaptable for use at higher frequencies.

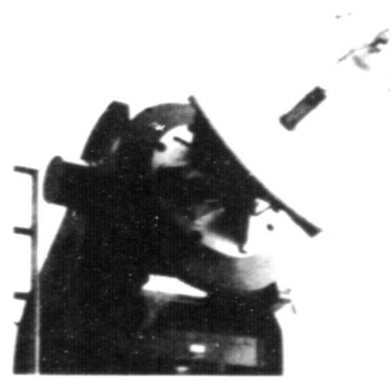
The remaining picture shows a frequency synthesizer building block suitable for low-cost spread spectrum modems or other equipments which require precise rapid tuning.

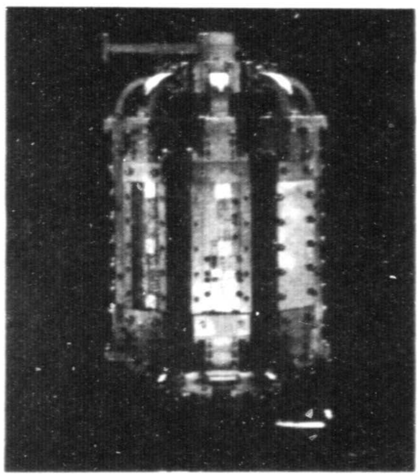
Additionally, work is being done on laser communications.

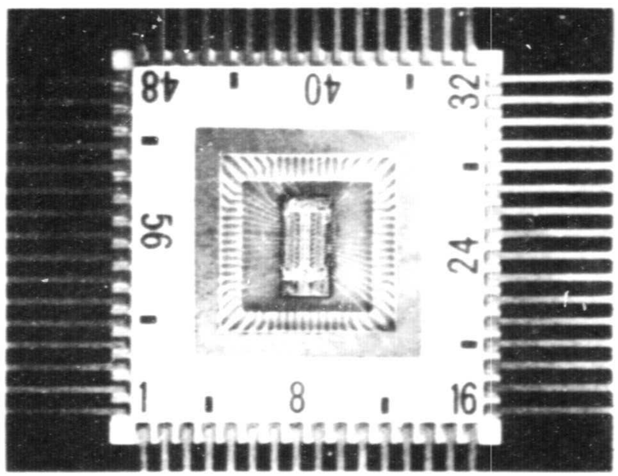
COMMUNICATIONS TECHNOLOGY


TDRSS MULTIPLE ACCESS PHASED ARRAY

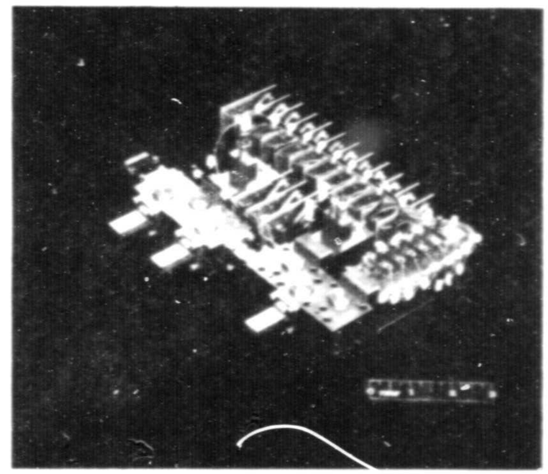

MM-WAVE DEVICES


ANTENNA Ku-BAND


20 GHz GaAs FET AMPLIFIER



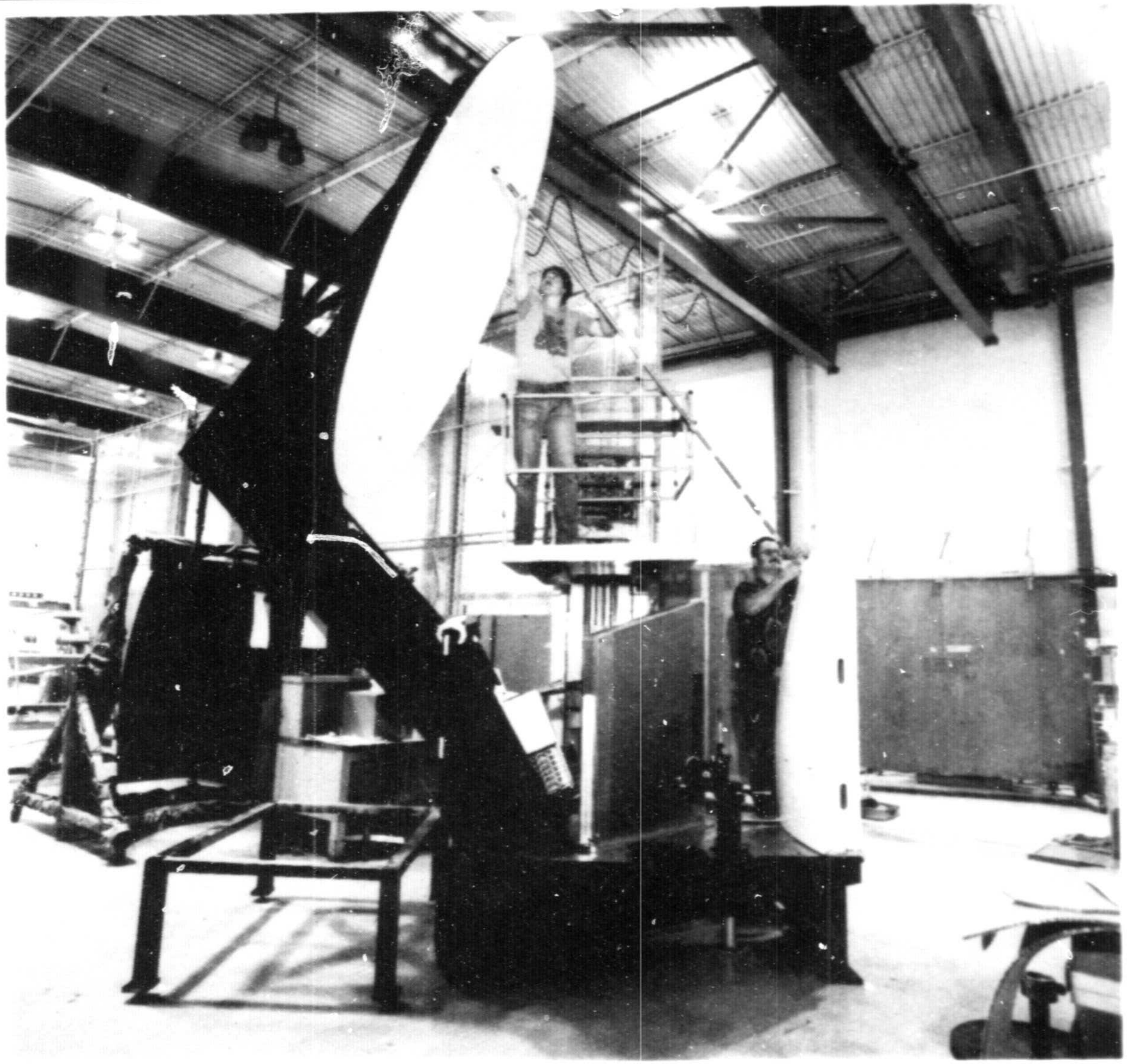
FREQUENCY SYNTHESIZER BUILDING BLOCK


20 GHz IMPATT AMPLIFIER

OFFSET ELECTRICALLY-STEERABLE ANTENNA

Shown is a proof of concept model of an offset reflector antenna for the NASA ACT program with multiple receiver beams at 30 GHz and transmit beams at 20 GHz. The offset configuration permits the use of large numbers of feed horns and an oversized primary reflector and polarizer without the loss of performance due to aperture blockage. Shaped (multiple feed) fixed beams and scanning beams may be used simultaneously. The configuration uses complex computer aided design algorithms which have only recently become available.

OFFSET ELECTRICALLY-STEERABLE ANTENNA



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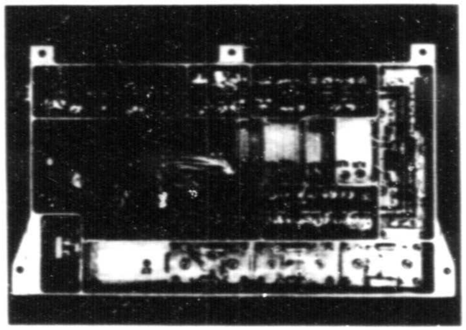
WIDEBAND SUBSYSTEM HARDWARE

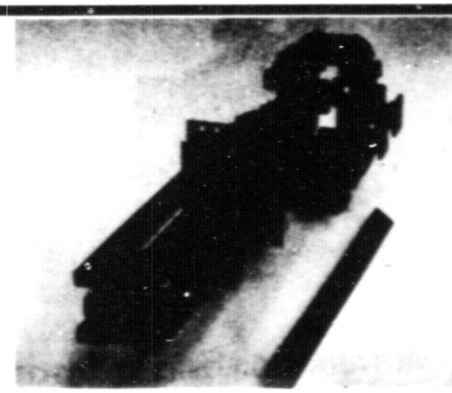
Shown are various elements of communications hardware developed for current programs at TRW.

WIDEBAND SUBSYSTEM HARDWARE



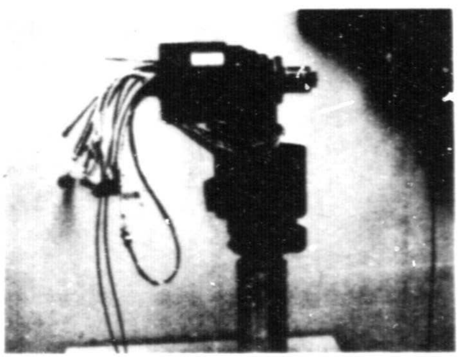
AUTOTRACK RECEIVER

- DEMODULATES AND DEMULTIPLEXES TRACKING SIGNAL INTO AZIMUTH AND ELEVATION ERRORS
- PROVIDES REFERENCE MULTIPLEXING SIGNAL TO AUTOTRACK COMBINER
- PROVIDES SIGNAL STRENGTH AND TRACKING ERROR SIGNALS TO ONBOARD COMPUTER



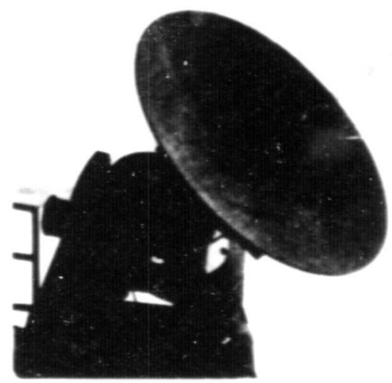
AUTOTRACK FEED/COMPARATOR

- PROVIDES TWO-AXIS MONOPULSE AUTOTRACK ERROR SIGNALS
- 5-HORN Ku-BAND TRACKING FEED



GIMBAL DRIVE ASSEMBLY

- FULLY REDUNDANT MOTORS, RESOLVERS AND BEARINGS
- LUBRICATION SYSTEM DERIVED FROM DSCS II ANTENNA DRIVE



Ku/S-BAND ANTENNA

- 70-INCH CASSEGRAIN ANTENNA
- 12-INCH DICHROIC SUBREFLECTOR
- FOCAL POINT S-BAND FEED

TECHNOLOGY DEVELOPMENT MISSIONS
(TDMs)
FOR
EARLY SPACE STATION

TOPICS FOR DISCUSSION

- WHAT IS A TDM?
- DISCUSSION OF SPECIFIC TDMS RECOMMENDED BY TRW
- TDMS FROM MSFC'S SATELLITE SERVICING TDM STUDY CONTRACT WITH TRW
- OTHER CANDIDATE TDMS
- CONCLUSIONS AND RECOMMENDATIONS

TDM - A DEFINITION

TRW has used as a definition of a TDM, the definition provided by NASA. That definition narrows a TDM to a technology development which uses the space station. It derives a unique benefit by using the space station. A given TDM may, of course, be part of a total technology development with precursor tests using the STS and/or performed on the ground. The benefit of all technology elements developed as part of a TDM is to further the exploration of space. Each TDM, to be cost effective, must consider and quantify benefit versus cost. One way to avoid unrealistic cost is to plan TDMs which are not dead-ended i.e., have a residual value.

TDM - A DEFINITION

- A TECHNOLOGY DEVELOPMENT MISSION (TDM) IS:
  - AN EXPERIMENTAL PROJECT AIMED AT SPACE TECHNOLOGY ADVANCEMENT
  - RECEIVES SUPPORT FROM THE SPACE STATION
- TDMs CAN:
  - HAVE VALUE FOR SCIENCE, APPLICATIONS, COMMERCIAL USES, NATIONAL SECURITY AND ENHANCEMENT OF NASA CAPABILITIES AND ROLE IN SPACE
  - DEVELOP TECHNOLOGY FOR LATER GENERATION SPACE STATIONS
  - INFLUENCE THE INITIAL SPACE STATION DESIGN
- TDMs WITH THEIR PROJECTED BENEFIT, IDEALLY, ARE INTERWOVEN WITH OTHER SPACE MISSIONS HAVING VALUE OF THEIR OWN

TDM SELECTION CRITERIA

The chart lists ten criteria and selection factors which TRW formulated as a guide to the selection of specific TDM missions from the larger candidate list. The first four are principal criteria to be met by the candidate missions to qualify for selection. The other six selection factors also express important considerations in the systematic selection process.

TDM SELECTION CRITERIA

PRINCIPAL CRITERIA

1. PERFORMS USEFUL MISSION I.E., NOT DEAD-ENDED
2. SERVES TO DEVELOP/DEMONSTRATE A SPACE-RELATED TECHNOLOGY
3. COMBINES SEVERAL TECHNOLOGY DEVELOPMENT OBJECTIVES
4. IS REALISTIC AS TO PROJECTED COST, SCHEDULE AND SUPPORT EQUIPMENT REQUIREMENTS

OTHER SELECTION FACTORS:

1. SPACE STATION CREW USED EFFECTIVELY
2. REQUIRED OPERATIONS EXCEED ORBITER STAY TIME
3. HAVE EVOLUTIONARY GROWTH POTENTIAL
4. INVOLVE SIGNIFICANT NEW TECHNOLOGY, DESIGN OR OPERATION
5. SATISFIES SEVERAL PROGRAM OBJECTIVES
6. SUPPORTS VARIETY OF OPERATIONS/EXPERIMENTS OR MISSIONS

TDMs RECOMMENDED BY TRW

The eight TDMs listed on the vu-graph were selected during the course of this SS study. Each of these eight will be discussed on subsequent charts.

Our Satellite Servicing study for NASA/MSFC has resulted in five additional SS-related TDMs. A more detailed discussion of these five TDMs concludes this section of the briefing.

TDMs RECOMMENDED BY TRW

- THE FOLLOWING CHARTS DISCUSS THE FOLLOWING SPECIFIC TDMs RECOMMENDED BY TRW

    1) COMMUNICATIONS SYSTEM TESTING
    2) COMMERCIAL MPS RESEARCH
    3) COMMERCIAL EARTH SENSOR DEVELOPMENT
    4) CONTROL SYSTEM DEMONSTRATION
    5) LARGE STRUCTURE MODELING
    6) PRECISION STRUCTURE ASSEMBLY
    7) ADVANCED PROPULSION TECHNOLOGIES
    8) PLANETARY AUTOMATED ORBIT OPERATIONS

- THESE TDMs ARE IN ADDITION TO FIVE BEING STUDIED IN OUR SATELLITE SERVICING TDM STUDY FOR MSFC

TDM FOR COMMUNICATIONS SYSTEM TESTING

This TDM tests commercial communications transmitting systems. Large antennas for, as an example, spot beam mobile communications antennas will be tested. Radiation patterns will be measured, Ka band propagation studied and adaptive shape control evaluated. This type of large antenna experimentation would be very difficult to do in the 1g earth environment. Testing at a LEO space station is substantially cheaper than comparable testing at GEO, the ultimate location of such communication systems. The technology elements of this TDM are also applicable to VLBI and radio astronomy antennas. This TDM is similar to TDM #3 of TRW's satellite servicing TDM study.

TDM FOR COMMUNICATIONS SYSTEM TESTING

- KEY TECHNOLOGY OBJECTIVES
  - DEVELOP METHODS FOR CONSTRUCTING, SHAPING AND MEASURING PERFORMANCE OF VERY LARGE ANTENNAS
  - VERIFY ON-ORBIT USE OF LASER TECHNOLOGY FOR ALIGNMENT
- KEY BENEFITS
  - ESTABLISH CONFIDENCE IN PRACTICALITY OF LARGE SPOT BEAM ANTENNAS IN SPACE
  - REDUCE RISK IN ESTABLISHING MOBILE COMMUNICATIONS SYSTEMS
- ADVANTAGE OF SPACE STATION
  - PROVIDES EXTENDED UNINTERUPTED TIME ON-ORBIT FOR CONSTRUCTION AND MEASUREMENT
- REQUIREMENTS IMPOSED ON SPACE STATION
  - ATTITUDE CONTROL WITH LARGE (50M) FLEXIBLE BODY ATTACHED
  - SYSTEM FOR PRECISION MEASURING ANTENNA SHAPE

TDM FOR COMMERCIAL MPS RESEARCH

This TDM provides the opportunity for commercially applicable research in low-gravity processing of many types of material. The space station is equipped with a general purpose shirtsleeve materials experimentation laboratory for this TDM. This TDM will lead toward confirmation of technologies needed for large scale commercialized production of unique materials in space.

TDM FOR COMMERCIAL MPS RESEARCH

- KEY TECHNOLOGY OBJECTIVES
  - EVOLVE METHODS AND TECHNIQUES FOR LOW GRAVITY MATERIAL PROCESSING
  - CATALOG DATA ABOUT MATERIALS PROCESSED IN LOW GRAVITY
- KEY BENEFITS
  - IDENTIFY PRODUCTS WITH COMMERCIAL APPLICATION AND PAYOFF
  - ADVANCE GENERAL MATERIALS TECHNOLOGIES
- ADVANTAGE OF SPACE STATION
  - EXTENDED TIME AVAILABLE FOR CLOSE-COUPLED SERIES OF EXPERIMENTS
  - MAN AVAILABLE FOR OBSERVATION AND EXPERIMENT MANIPULATION
- REQUIREMENTS IMPOSED ON SPACE STATION
  - NEED FOR A SHIRT-SLEEVE GENERAL PURPOSE MATERIALS EXPERIMENTATION LABORATORY

TDM FOR COMMERCIAL EARTH SENSOR DEVELOPMENT

This TDM is the vehicle for testing and developing the technology related to advanced earth sensing instruments. Refinement and improvement of existing instruments is of significant value in advancing acquisition of commercially useful earth and ocean data.

TDM FOR COMMERCIAL EARTH SENSOR DEVELOPMENT

- KEY TECHNOLOGY OBJECTIVES
  - VERIFY PERFORMANCE AND CAPABILITIES OF NEW-DESIGN EARTH RESOURCE SENSORS HAVING HIGHER RESOLUTION, COVERING MORE SPECTRAL BANDS, HAVING HIGHER SENSITIVITY, ETC.
- KEY BENEFITS
  - IMPROVED COMMERCIAL OPERATIONS AND BETTER SCIENCE RESULTING FROM IMPROVED INSTRUMENTS
- ADVANTAGE OF SPACE STATION
  - LONG TERM TESTING TIME WITHOUT NEED FOR SEPARATE, COSTLY FREE-FLYING SPACECRAFT FOR INSTRUMENT DEVELOPMENT
  - MAN AVAILABLE FOR TEST MANIPULATION
- REQUIREMENTS IMPOSED ON SPACE STATION
  - EARTH-VIEWING PORT
  - POWER, DATA HANDLING AND OTHER SERVICES

TDM FOR CONTROL SYSTEM DEMONSTRATION

Active vibration suppression and shape control of large, very flexible structures are of critical importance to the space station and future large, flexible structures in space. This TDM will conduct experiments involving several approaches to active control of flexible structures such as multivariable and adaptive control. Control laws will be validated. The test structure will include bending moment actuators and various sensor types. Data will be gathered to evaluate trades between structural stiffness and weight as well as between control hardware complexity and weight.

TDM FOR CONTROL SYSTEM DEMONSTRATION

- KEY TECHNOLOGY OBJECTIVES
  - GATHER BASIC DATA APPLICABLE TO ACTIVE VIBRATION SUPPRESSION AND SHAPE CONTROL OF LARGE, FLEXIBLE STRUCTURES
- KEY BENEFITS
  - PROVIDE DESIGN DATA SO RISK OF USING LARGE, FLEXIBLE ELEMENTS (STRUCTURES, ARRAYS, ANTENNAS) IN SPACE IS REDUCED
- ADVANTAGE OF SPACE STATION
  - TIME TO CONDUCT TEST IS NOT CONSTRAINED BY STS ON-ORBIT STAY TIME
  - SEPARATE EXPENSIVE FREE-FLYER TEST BED IS NOT REQUIRED
- REQUIREMENTS IMPOSED ON SPACE STATION
  - ATTACHMENT PORT OR PLATFORM FOR LARGE STRUCTURE
  - DYNAMIC STABILITY WITH LARGE STRUCTURE ATTACHED

TDM FOR LARGE STRUCTURE MODELING

This TDM will experimentally demonstrate large flexible structure modeling technology. The understanding gathered from these experiments is important to active control system design where such large flexible structures are in the control loop. The tests of this TDM will confirm the ability of structural modeling and model synthesis techniques to predict the modal characteristics and structural damping of a test structure. Successful completion of the TDM will provide confidence in similar predictions for other large space structures. Test verification methods will also be validated and remain in place for use in testing future structures.

TDM FOR
LARGE STRUCTURE MODELING

- KEY TECHNOLOGY OBJECTIVES
  - DEMONSTRATE AND VERIFY LARGE STRUCTURE MODELING AND MODAL SYNTHESIS TECHNIQUES (TEST OF LARGE STRUCTURES IN ONE G IS NOT PRACTICAL)
- KEY BENEFITS
  - ASSURE VALIDITY OF ANALYTIC TOOLS USED TO MODEL CONTROL SYSTEMS WHERE LARGE, FLEXIBLE STRUCTURES EXIST
- ADVANTAGE OF SPACE STATION
  - TIME TO CONDUCT TEST IS NOT CONSTRAINED BY STS ON-ORBIT STAY TIME
  - SEPARATE EXPENSIVE FREE-FLYER TEST BED IS NOT REQUIRED
- REQUIREMENTS IMPOSED ON SPACE STATION
  - ATTACHMENT PORT OR PLATFORM FOR LARGE STRUCTURE
  - DYNAMIC STABILITY WITH LARGE STRUCTURES ATTACHED

TDM FOR PRECISION STRUCTURE ASSEMBLY

This TDM is to develop technology for on orbit assembly, alignment, and calibration of large precision structures. These structures will be required for large optical telescopes, radio antennas and arrays.

The technology of assembly, alignment and calibration of large precision structures in space will differ markedly from that currently used on the ground. The 0-g environment and readily available RF and optical alignment references offer opportunities for new performance levels and possibly lower costs given the availability of a space station. Assembly and alignment fixtures on the space station would be used to construct test instruments, e.g., telescope optical benches and precision antennas. This equipment would facilitate evaluation of techniques and capabilities.

This technology would enhance precision instrument performance for use in science, applications, commercial and military endeavors and would provide for lower cost deployment of large, precision instruments.

TDM FOR PRECISION STRUCTURE ASSEMBLY

- KEY TECHNOLOGY OBJECTIVES
  - DEVELOP TECHNOLOGY FOR ON-ORBIT ASSEMBLY, ALIGNMENT AND CALIBRATION OF LARGE PRECISION STRUCTURES SUCH AS REQUIRED FOR LARGE OPTICAL TELESCOPES, RADIO ANTENNAS AND ARRAYS
- KEY BENEFITS
  - ENHANCE PRECISION INSTRUMENT PERFORMANCE AND REDUCE DEVELOPMENT COSTS FOR USE IN SCIENCE, APPLICATIONS, COMMERCIAL AND MILITARY ENDEAVORS
- ADVANTAGE OF SPACE STATION
  - LONG DURATION FACILITY
  - MAN AVAILABILITY
  - AVAILABLE SS FACILITIES, MANIPULATORS
- REQUIREMENTS IMPOSED ON SPACE STATION
  - EXPECT TO USE GENERALLY AVAILABLE FACILITIES FOR ASSEMBLY HANDLING
  - REQUIRE SPACE STATION TIME, SPACE AND MANPOWER RESOURCES

TDM FOR ADVANCED PROPULSION TECHNOLOGIES

The purpose of this TDM is to test advanced propulsion technologies such as electrical propulsion that are best or more easily evaluated in a space environment. Propulsion modules are mounted on the space station and operated to evaluate their performance, reliability and environmental effects.

On-orbit propulsion test facilities can potentially provide lower cost of testing advanced technologies such as electric propulsion. In the past, electric propulsion development has been impeded because of the difficulty of completely testing the technology on earth.

The availability of economic propulsion test facilities in space will shorten the development cycle for advanced technologies and enable advanced science missions such as comet rendezvous that require large transfer velocities.

TDM FOR
ADVANCED PROPULSION TECHNOLOGIES

- KEY TECHNOLOGY OBJECTIVES
  - TEST ADVANCED PROPULSION TECHNOLOGIES SUCH AS ELECTRIC, NUCLEAR, ISOTOPE PROPULSION THAT ARE BEST OR MORE EASILY EVALUATED IN A SPACE ENVIRONMENT
- KEY BENEFITS
  - ADVANCE HIGHER PERFORMANCE PROPULSION TECHNOLOGIES FOR ORBIT TRANSFER AND PLANETARY MISSIONS
- ADVANTAGE OF SPACE STATION
  - LONG DURATION FACILITY FOR LOWER COST SET UP AND MONITORING OF TESTS REQUIRING SPACE ENVIRONMENT, LARGE VOLUMES AND/OR SAFE, REMOTE OPERATION
- REQUIREMENTS IMPOSED ON SPACE STATION
  - EXPECT TO USE GENERALLY AVAILABLE SS HANDLING, SERVICING AND COMMUNICATIONS FACILITIES
  - REQUIRE SS TIME, SPACE AND MANPOWER RESOURCES

TDM FOR PLANETARY AUTOMATED ORBIT OPERATIONS

The purpose of this TDM is to validate remote automated rendezvous and sample return capture technologies useable for complex planetary missions such as Mars Surface Sample Return and Comet Sample Return.

This TDM would have two phases:

1. Automated Planetary Rendezvous: Deploy in earth orbit two test vehicles and simulate orbital rendezvous at a distant planet, e.g., Mars. These vehicles could be prototype articles or functional simulators.
2. Sample Capture: A simulated sample return capsule could be boosted and de-boosted to simulate high energy approach. Earth aerocapture would be tested as well as capture by OTV and/or TMS.

These types of tests would permit complex planetary operations, e.g., Mars surface sample acquisition and return and comet sample return with greater assurance providing new capabilities for unprecedented science return.

These tests and demonstrations would avoid expensive ground tests, simulations, and designs to otherwise assure these capabilities.

TDM FOR
PLANETARY AUTOMATED ORBIT OPERATIONS

- KEY TECHNOLOGY OBJECTIVES
  - VALIDATE CONCEPTS AND DESIGNS FOR REMOTE AUTOMATED RENDEZVOUS AND SAMPLE RETURN CAPTURE TECHNOLOGIES
- KEY BENEFITS
  - LOWER COST AND RISK OF DEVELOPING TECHNOLOGIES NECESSARY FOR COMPLEX PLANETARY MISSIONS SUCH AS MARS SURFACE SAMPLE RETURN AND COMET SAMPLE RETURN, CANDIDATES FOR FLIGHTS IN THE 1990'S
- ADVANTAGE OF SPACE STATION
  - LONG DURATION FACILITY FOR LOWER COST SET UP AND NEAR-BY MONITORING OF TEST HARDWARE, PROTOTYPE ARTICLES OR FUNCTIONAL SIMULATORS
- REQUIREMENTS IMPOSED ON SPACE STATION
  - EXPECT TO USE GENERALLY AVAILABLE SS HANDLING, SERVICING AND COMMUNICATION FACILITIES
  - REQUIRE SS TIME, SPACE AND MANPOWER RESOURCES

STUDY CONTRACT FOR SATELLITE SERVICING TDMs

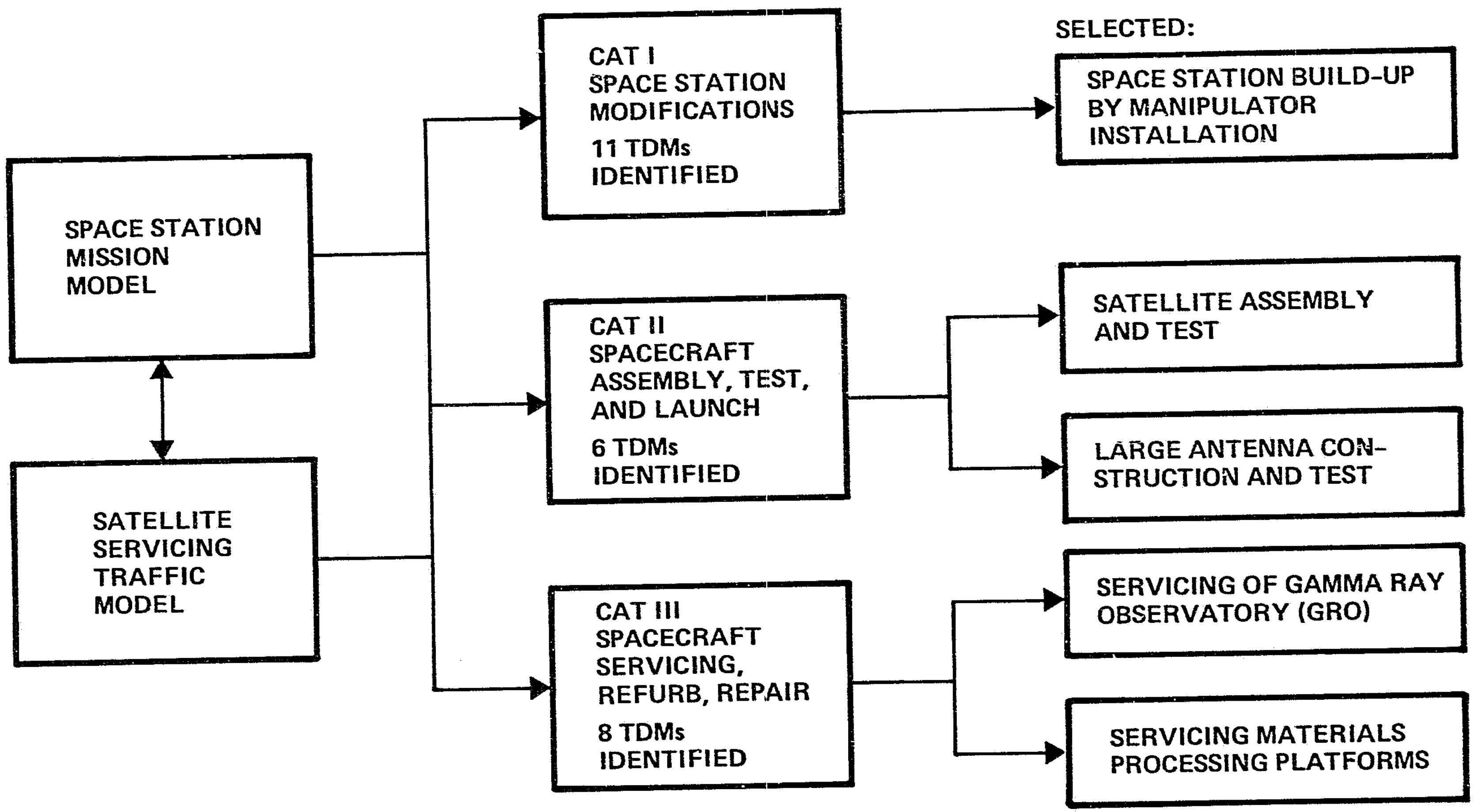
- TRW IS UNDER CONTRACT TO NASA/MSFC TO EVOLVE AND RECOMMEND TDMs RELATED TO SATELLITE SERVICING
- THE STUDY TITLE IS:

  "DEFINITION OF SATELLITE SERVICING TECHNOLOGY DEVELOPMENT MISSIONS FOR EARLY SPACE STATIONS"
- TDMs RELATED TO LARGE SPACE STRUCTURES AND OTVs ARE BEING STUDIED VIA SIMILAR CONTRACTS WITH OTHER CONTRACTORS
- THE FOLLOWING CHARTS DISCUSS THE TDMs BEING DEVELOPED IN TRW'S STUDY

SATELLITE SERVICING TDM STUDY: TWENTY-FIVE TDMs IDENTIFIED - FIVE SELECTED FOR DESIGN

In the Satellite Servicing TDM Study by TRW for MSFC (Contract NAS8-35081 "Definition of Satellite Servicing Technology Development Missions for Early Space Stations), TRW has identified twenty-five candidate TDMs. These candidate TDMs are divided into three categories as shown in the chart. Of these twenty-five candidates, five have been selected for detail design.

SATELLITE SERVICING TDM STUDY: TWENTY-FIVE TDMs IDENTIFIED: FIVE SELECTED FOR DESIGN

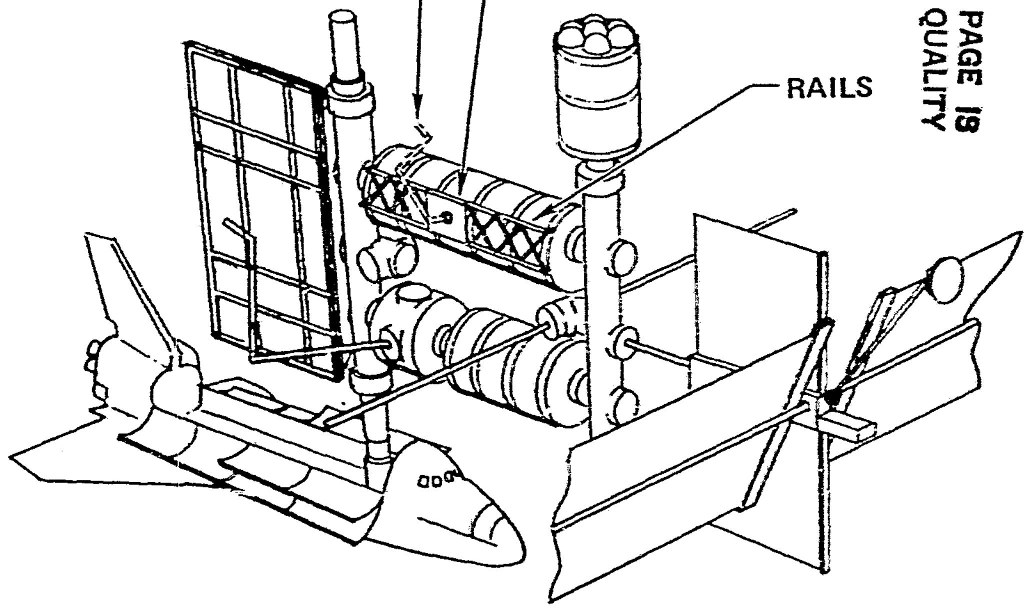


SATELLITE SERVICING - TDM #1: SUMMARY SS MANIPULATOR TRACK INSTALLATION

TDM #1 involves the construction of a track system to support a moveable manipulator arm on the early space station. A fixed manipulator arm is assumed to be in place prior to the start of this mission. The track system is assembled on-orbit from small parts delivered via STS. A later STS assists in transferring the space station RMS to the track system, using the STS RMS.

SATELLITE SERVICING - TDM #1 SUMMARY
SS MANIPULATOR TRACK INSTALLATION

1. TECHNOLOGY DEVELOPMENT ELEMENTS
   - EVA CONSTRUCTION
   - ON ORBIT MISSION PLANNING
   - ON ORBIT EVENT SCHEDULING
   - ON ORBIT SYSTEM/SUBSYSTEM TEST
   - SPACE STATION INTERNAL INSTALLATIONS
   - ON ORBIT LOGISTICS CONTROL



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2. BENEFITS
   - DEVELOP ON ORBIT ASSEMBLY TECHNIQUES
   - ENHANCE SS LOAD HANDLING CAPABILITY
   - SUPPORT SUBSEQUENT SS MODIFICATIONS

3. SPACE STATION REQUIREMENTS SUMMARY
   - STORAGE PROVISIONS ON SS FOR BUILDING MATERIALS
   - SPECIAL CREW TRAINING, PROCEDURES
   - SPECIAL CREW SUPPORT EQUIPMENT, INSTALLATION TOOLS

4. SCENARIO HIGHLIGHTS
   - SHUTTLE DELIVERS RMS, RAILS AND OTHER BUILDING MATERIAL
   - SHUTTLE RMS ASSISTS EVA CREW IN CONSTRUCTION
   - CREW COMPLETES INSTALLATION, PERFORMS CHECKOUT AND FUNCTIONAL TESTS

SATELLITE SERVICING - TDM #2 SUMMARY: SPACECRAFT ASSEMBLY, TEST AND LAUNCH

This TDM involves the on-orbit assembly, test, fueling, and launch of a modular spacecraft that may exceed the volume capacity of a single shuttle launch.

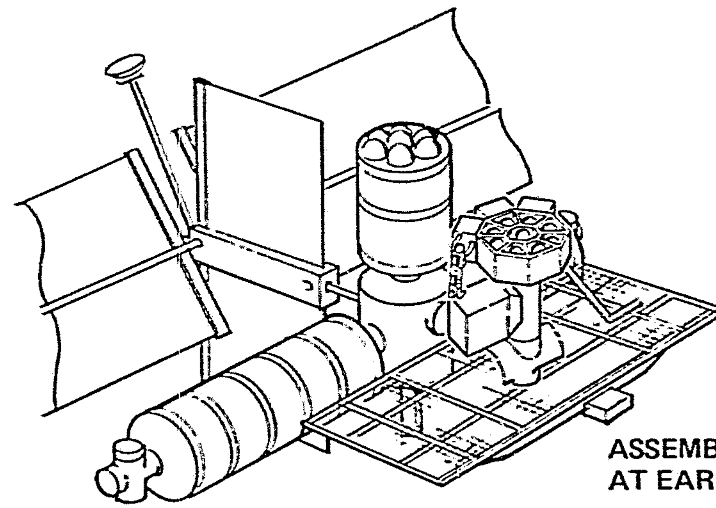
The spacecraft is designed for on-orbit assembly and test and extensive support equipment and procedures are required.

SATELLITE SERVICING - TDM #2 SUMMARY
SPACECRAFT ASSEMBLY TEST AND LAUNCH

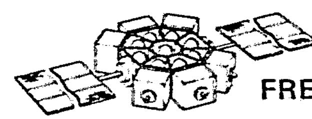
1. TECHNOLOGY DEVELOPMENT ELEMENTS
   - EVA CONSTRUCTION
   - ON ORBIT REFUELING
   - ON ORBIT MISSION PLANNING
   - ON ORBIT TARGETING OF AUTONOMOUS GUIDANCE
   - ON ORBIT EVENT SCHEDULING
   - ON ORBIT SYSTEM/SUBSYSTEM TEST

2. BENEFITS
   - FINAL TEST ON ORBIT IMPROVES PROBABILITY OF MISSION SUCCESS
   - SPACECRAFT MAY EXCEED STS SIZE AND WEIGHT LIMITS

3. SPACE STATION REQUIREMENTS SUMMARY
   - STORAGE PROVISIONS ON SS
   - MODULE HANDLING BY RMS, AIDED BY CREW (EVA)
   - MECHANICAL AND ELECTRICAL FSE (GENERAL AND SPECIAL PURPOSE) NEEDED
   - SPECIALIZED CREW TRAINING, CREW SUPPORT EQUIPMENT
   - STANDARDIZED INTERFACE DESIGN



ASSEMBLY & FINAL TEST AT EARLY SPACE STATION



FREE FLYERS/PLATFORMS

4. SCENARIO HIGHLIGHTS
   - SPACECRAFT MODULES DELIVERED ON SUCCESSIVE SHUTTLE VISITS
   - STORED ON-BOARD SS
   - ASSEMBLED, CHECKED-OUT, TESTED BY SS CREW, PARTLY IN EVA MODE
   - CREW ASSISTS IN APPENDAGE DEPLOYMENT
   - CREW PREPARES SPACECRAFT FOR AND ACCOMPLISHES LAUNCH

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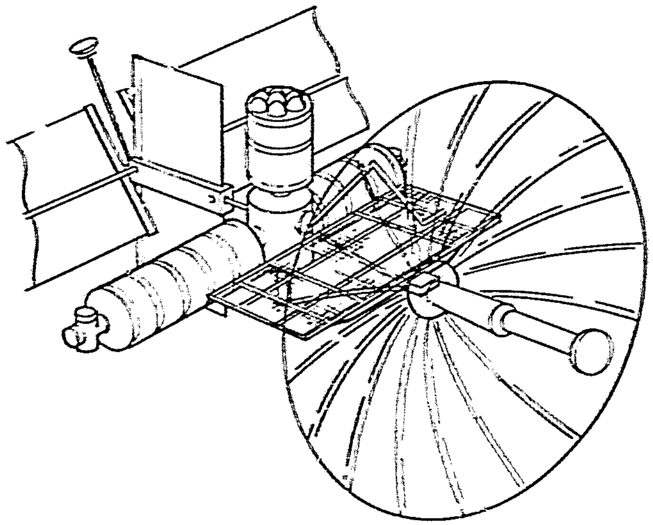
SATELLITE SERVICING - TDM #3 SUMMARY:LARGE ANTENNA STRUCTURE DEPLOYMENT

Construction of large antennas in orbit involves problems in achieving precise geometrics of large structures and in measuring and adjusting the antenna pattern. Far field measurements may require the test receiver to be many miles from the antenna. Because of the deforming effects of gravity, final antenna geometry adjustments are best done on orbit. This TDM is designed to develop the technologies required for these types of operations.

SATELLITE SERVICING - TDM #3 SUMMARY
LARGE ANTENNA STRUCTURE DEPLOYMENT

1. TECHNOLOGY DEVELOPMENT ELEMENTS
   - EVA CONSTRUCTION
   - TMS OPERATIONS
   - AUTOMATED ANTENNA GEOMETRY SYSTEMS
   - ON ORBIT MISSION PLANNING
   - ON ORBIT EVENT SCHEDULING
   - ON ORBIT SYSTEM/SUBSYSTEM TEST
2. BENEFITS
   - ANTENNAS MAY EXCEED SIZE AND WEIGHT LIMITATIONS OF SHUTTLE
   - PRECISE GEOMETRIES MAY BE ACHIEVED
3. SPACE STATION REQUIREMENTS SUMMARY
   - SPECIALIZED MECHANICAL AND CREW SUPPORT EQUIPMENT
   - OPTICAL/LASER SHAPE MONITORING
   - SHAPE CONTROL TECHNIQUES
   - PRECISION TRACKING AND CONTROL OF FREE FLYING (TMS) RECEIVER LOCATION
   - SPECIALIZED CREW TRAINING



4. SCENARIO HIGHLIGHTS
   - SHUTTLE DELIVERS FOLDED ANTENNA STRUCTURE
   - CREW ERECTS ANTENNA DISH, AIDED BY LASER OR PASSIVE OPTICAL MEASUREMENTS
   - FREE FLYING PROBE (TMS) MEASURES ANTENNA PATTERN
   - ANTENNA TRIMMING AS REQUIRED

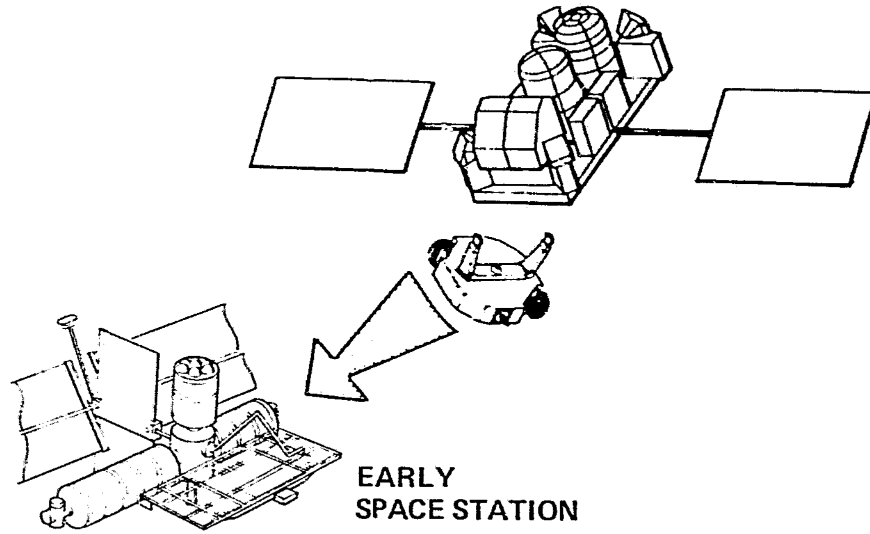
SATELLITE SERVICING - TDM #4 SUMMARY: GRO REFURBISHMENT/REPAIR

This mission makes use of an existing satellite at its planned end of life. Because mission time constraints are not significant compared to a shuttle mission, even units not designed for on orbit repair may be serviceable.

This mission may be thought of as a generic on-orbit satellite refurbishment mission for the space station.

SATELLITE SERVICING - TDM #4 SUMMARY
GRO REFURBISHMENT/REPAIR

1. TECHNOLOGY DEVELOPMENT ELEMENTS
   - EVA CONSTRUCTION/DISASSEMBLY
   - ON ORBIT REFUELING
   - TMS OPERATIONS
   - SMALL PART REPLACEMENT
   - ON ORBIT MISSION PLANNING
   - ON ORBIT EVENT SCHEDULING
   - ON ORBIT SYSTEM/SUBSYSTEM TEST
   - REMOTE REBOOST USING TMS
   - RETRIEVAL OF S/C USING TMS
2. BENEFITS
   - EXTENSION OF LIFE OF GRO
   - APPLICABLE TO REPAIR/REFURBISHMENT OF MANY OTHER S/C
3. SPACE STATION REQUIREMENTS
   - MECH AND ELECT SUPPORT EQUIPMENT
   - CREW SUPPORT EQUIPMENT
   - REFILLABLE PROPELLANT TANKS
   - SPECIAL CREW TRAINING



4. SCENARIO HIGHLIGHTS
   - GRO RETRIEVED FROM 400 KM ORBIT
   - COMPREHENSIVE STATUS TESTS
   - REFURBISHMENT/REPAIR OF UNITS
   - PROPELLANT REFILL
   - COMPREHENSIVE CHECKOUT
   - REDEPLOYMENT INTO OPERATIONAL ORBIT

SATELLITE SERVICING - TDM #5 SUMMARY: SERVICING OF FREE-FLYING MATERIALS PROCESSING PLATFORM

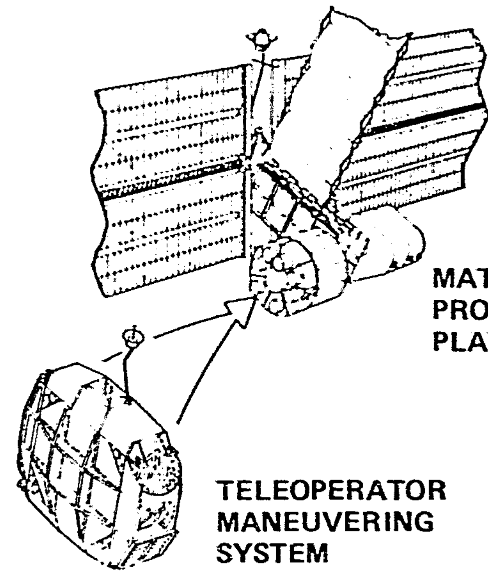
This TDM differs from the first four in that it is an open ended, pilot plant operation which can develop into a continuous operational mission. Only one servicing cycle is considered here. They should be all alike, unless repairs to the MPP become necessary. In this event the MPP would be returned to the space station.

SATELLITE SERVICING - TDM #5 SUMMARY
SERVICING OF FREE-FLYING MATERIALS PROCESSING PLATFORM

1. TECHNOLOGY DEVELOPMENT ELEMENTS
   - ON ORBIT MISSION PLANNING
   - ON ORBIT EVENT SCHEDULING
   - ON ORBIT LOGISTICS CONTROL
   - REMOTE RESUPPLY USING TMS
   - REMOTE REBOOST USING TMS

2. BENEFITS
   - ACHIEVE ROUTINE SUPPLY/HARVESTING, ESSENTIAL TO COMMERCIAL SPACE PROCESSING

3. SPACE STATION REQUIREMENTS
   - TMS WITH SERVICE ATTACHMENT OPERATIONAL
   - TV CONTROLLED REMOTE TMS OPERATIONS
   - SPACE PROCESSING PLATFORM DESIGNED FOR REMOTE SERVICING
   - RENDEZVOUS OPERATIONS SCHEDULE MONITORED AND CONTROLLED TO FACILITATE ROUTINE UNMANNED SERVICING SORTIES



4. SCENARIO HIGHLIGHTS
   - TMS DOCKS AT PLATFORM
   - TMS DELIVERS AND EXCHANGES SAMPLE MAGAZINES, RETURNS FINISHED SAMPLES TO SS
   - IN-SITU TMS OPERATIONS CONTROLLED REMOTELY FROM SS VIA TV LINK
   - TMS ALSO PERFORMS ORBIT REBOOST OF PLATFORM ON COMMAND FROM SS

OTHER TDM CANDIDATES

TRW has identified a number of other TDMs. We have not investigated them in detail nor are they documented in our users catalogue. They are, however, TDMs which would significantly advance space technology and would benefit from the space station.

OTHER TDM CANDIDATES

1. FLUID STORAGE/TRANSFER
   - CRYOGEN STORAGE/TRANSFER
2. TRANSFER VEHICLES
   - ROTV DEVELOPMENT
   - AEROBRAKE DESIGN RESEARCH
3. POWER SYSTEMS
   - LARGE SOLAR CONCENTRATOR DEVELOPMENT
   - NUCLEAR POWER PLANT DEMONSTRATION
4. THERMAL
   - MATERIALS AND COATINGS TECHNOLOGIES
   - RADIATOR TECHNOLOGIES
5. STRUCTURES
   - CONSTRUCTION METHODOLOGIES
   - LARGE STRUCTURE THERMAL STABILITY INVESTIGATION
6. BIO SCIENCES
   - CLOSED ECOSYSTEMS
   - HUMAN PHYSIOLOGY
7. LIFE SUPPORT
   - ARTIFICIAL GRAVITY METHODS
   - CLOSED SYSTEM SUIT DEMONSTRATIONS
   - ADVANCED EVA EXPERIMENTS
8. ROBOTICS
   - REMOTE (GEO) SERVICE
9. TETHER DEMONSTRATIONS
10. COMMUNICATIONS
    - LASER COMMUNICATION AND TRACKING SYSTEM VERIFICATION
11. DATA SYSTEMS
    - AUTO NAVIGATION DEMONSTRATION
    - SPACE STATION AUTONOMY EXPERIMENTS

CONCLUSIONS ON TDMS

- A SIGNIFICANT NUMBER OF TDMs HAVE BEEN IDENTIFIED FOR THE SPACE STATION ERA
- THE SPACE STATION DOES PROVIDE ECONOMIC AND PERFORMANCE BENEFIT IN CONDUCT OF THESE TDMs
- MANY OF THE TDMs DIRECTLY BENEFIT THE EVOLUTIONARY SPACE STATION
- TDMs REQUIRE ADDITIONAL STUDY TO 1) ASSESS THEIR TOTAL BENEFIT TO SPACE PROGRAMS AND 2) FURTHER DETAIL THEIR DESIGN